

Electric Control of a CVT for Motorcycles Using a Self-Locking Reduction Mechanism

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High efficiency is essential for small electric two-wheelers with battery constraints. The combination of a compact, high-speed motor and a transmission is effective for achieving high-efficiency operation and miniaturization; however, conventional weight-roller-type CVTs make it difficult to shift gears as desired, and electrically controlled CVTs face the challenge of reduced energy efficiency due to the power required to maintain pulley positions. Therefore, in this study, we propose an electrically controlled CVT that combines a shifting motor, a self-locking reduction mechanism, and a ball screw to maintain the gear ratio without power. We construct vehicle analysis models for both the conventional CVT and the proposed CVT mechanism, and quantitatively evaluate the improvement in energy efficiency by comparing battery consumption under WMTC mode.

MATLAB R2025b Simulink was used for the analysis. A closed-loop model was established in which the deviation between the target vehicle speed and the actual vehicle speed was input into the PID controller; the torque command value, limited by the speed-maximum torque characteristic, was then calculated and transmitted to the vehicle model to provide speed feedback. Regarding the gear ratios, Model A applied the gear ratio history of the weight-roller-type CVT from a previous study, while Models B and C were assigned optimal gear ratios that minimize power consumption. Model B is a virtual model that includes the power consumption of the shifting motor, while Model C is a virtual model that excludes only that component. The comparison between Models A and B evaluates the overall improvement in the system's energy efficiency, while the comparison between Models B and C assesses the impact of the shifting motor's power consumption.

Fig. 1 shows the SOC history for Model A and Model B. Net battery consumption was 33.19% for Model A and 30.29% for Model B. Therefore, compared to Model A, Model B achieved a reduction in net battery consumption of 2.90 points, or 8.74% in relative terms. In Model A, since the gear ratio is passively determined by the centrifugal force of the weight roller, the drive motor operates in the high-speed range depending on driving conditions. In contrast, in Model B, the gear ratio can be selected to minimize battery consumption at any given time; it is believed that shifting the drive motor's operating point to the high-efficiency range in this manner contributed to the reduction in total discharge. In this analysis, the power consumption of the shifting motor is added to the battery consumption only during gear shifts; during periods when the gear ratio remains constant, the power consumption of the shifting motor is set to 0 due to the self-locking action of the locking gear. As a result, the power consumption of the shifting motor resulted in a loss of 0.41 points, compared to the 3.73 point reduction in total discharge achieved through gear ratio control. The regenerative charging amount for Model B decreased by 0.42 points compared to Model A. Model A operates at a higher motor rotational speed than Model B during certain deceleration sections. This difference in rotational speed history is considered one of the factors contributing to Model A's higher regenerative charging amount compared to Model B. Table 1 shows the contributions of each factor. When the net reduction of 2.90 points is set as 100%, the effect of changing the operating point of the drive motor was 128.61%, the loss due to power consumption by the speed-control motor was 14.13%, and the loss due to the decrease in regenerative charging was 14.48%.

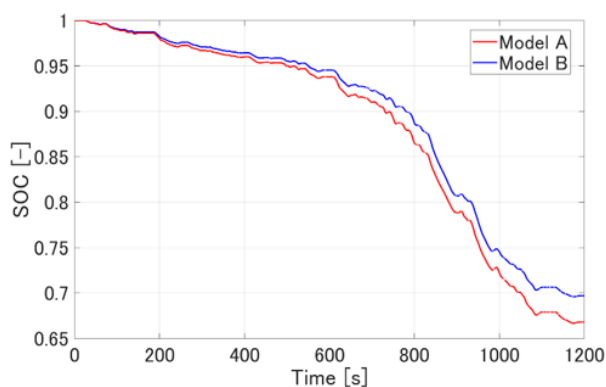


Fig. 1 SOC comparison between Model A and Model B

Table 1 Factors Contributing to Reduced Battery Consumption

	Point	Converted to a percentage
Improvements due to motor efficiency	3.73	128.61
Losses due to gear shifting motor	-0.41	-14.13
Losses due to differences in regeneration	-0.42	-14.48
Total consumption	2.90	100